

## CLAIMS

Having thus described the aforementioned invention, we claim:

1. An apparatus for automating the production of a radiopharmaceutical by executing a sequence of process flow operations, said apparatus comprising:

5 a workstation having a processing component programmed to execute a process including the steps of:

providing a recipe editor for creating and maintaining a recipe,

providing operations control for executing said recipe, and

10 displaying at least one process variable during execution of said recipe;

a controller having an input/output component and a processing component, said controller communicating with said workstation, said controller processing component programmed to execute a process including the steps of:

15 receiving a plurality of unit operations forming said recipe, each said unit operation describing a chemical process step,

receiving a command to begin execution of said recipe,

performing an execution loop wherein said plurality of unit operations are executed, said execution loop including the steps of:

20 executing one of said plurality of unit operations starting a parallel group,

classifying a next one of said plurality of unit operations as one of a parallel operation and a sequential operation,

executing said parallel operation as part of said parallel group and repeating said step of classifying,

waiting for said parallel group to complete execution,  
executing said sequential operation and starting a new parallel  
group, and  
repeating said step of classifying; and

5 a plurality of process hardware in communication with a plurality of  
input/output points included in said input/output component of said controller  
and responsive to at least one control signal from said controller, said plurality of  
process hardware adapted to produce the radiopharmaceutical and including a  
reagent delivery system and a reaction vessel with an associated heating and  
10 purging system.

2. The apparatus of Claim 1 wherein each of said plurality of unit  
operations describes a process flow step in terms of the chemical and physical  
steps to be performed.

3. The apparatus of Claim 1 wherein each of said plurality of unit  
15 operations calls a software routine programmed to perform a set of instructions to  
manipulate said plurality of process hardware to perform a process flow step.

4. The apparatus of Claim 1 wherein said workstation communicates  
said recipe and at least one command to a process control program being executed  
by said controller.

20 5. The apparatus of Claim 1 wherein a process control program being  
executed by said controller communicates a recipe state and at least one device  
state to said workstation.

6. The apparatus of Claim 1 wherein said process step of providing  
operations control being executed by said workstation processing component  
25 includes the steps of:

selecting said recipe for execution from a library,

sending said recipe to said controller, and

sending an execute command to said controller.

7. The apparatus of Claim 6 wherein said step of sending said recipe  
5 includes sending said plurality of unit operations to said controller.

8. The apparatus of Claim 6 wherein said process step of providing  
operations control further includes the step of receiving a stream of data from said  
controller, said stream of data including a recipe state, at least one unit operation  
state, and at least one device state.

10 9. The apparatus of Claim 6 wherein said process step of providing  
operations control further includes sending a reset command to said controller  
before said step of sending said recipe to said controller.

10. The apparatus of Claim 1 wherein said controller processing  
component is programmed to execute a process further including receiving a reset  
15 command and initializing said controller before said step of receiving said plurality  
of unit operations.

11. The apparatus of Claim 1 wherein said controller processing  
component includes a process control program and a hardware control program,  
said process control program including a step of communicating with said  
20 hardware control program.

12. The apparatus of Claim 1 wherein said controller processing  
component includes a process control program and a hardware control program,  
said hardware control program having a plurality of instructions executable by the  
controller, said hardware control program including a step of communicating with

said process control program and a step of communicating with said plurality of process hardware.

13. The apparatus of Claim 1 wherein said controller processing component includes a process control program and a hardware control program,  
5 said process control program having a lookup table correlating each of said plurality of input/output points to a corresponding device, said process control program receiving data from one of said plurality of input/output points and said process control program executing a step to determine said corresponding device.

14. The apparatus of Claim 1 wherein said controller processing  
10 component includes a process control program and a hardware control program, said hardware control program having a lookup table correlating each of said plurality of devices to each of said input/output points whereby said hardware control program receives instructions to be communicated to one of said plurality of devices and said hardware control program executes a step to determine said  
15 corresponding input/output point.

15. The apparatus of Claim 1 wherein said controller processing component includes a process control program and a hardware control program, said hardware control program having a plurality of instructions executable by said controller processing component for data acquisition from a plurality of selected  
20 devices of said plurality of process hardware, and said hardware control program sending a plurality of acquired information to said process control program.

16. A method in a computer system for automating a sequence of process flow operations, said method comprising:

receiving a recipe by a process control module, said recipe including a  
25 plurality of unit operations, each of said plurality of unit operations describing a process flow step in terms of at least one chemical and/or physical step to be performed;

receiving a command to begin execution of said recipe by said process control module; and

performing an execution loop wherein said plurality of unit operations are executed, said execution loop including the steps of:

5                   executing one of said plurality of unit operations and starting a parallel group,

                  classifying a next one of said plurality of unit operations as one of a parallel operation and a sequential operation,

10                  executing said parallel operation as part of said parallel group and repeating said step of classifying,

                  waiting for said parallel group to complete execution,

                  executing said sequential operation and starting a new parallel group, and

                  repeating said step of classifying.

15                  17.   The method of Claim 16 wherein each of said step of executing said parallel operation and said step of executing said sequential operation includes the step of passing a set of data from said process control module to a hardware control module, said hardware control module performing a set of instructions to manipulate a plurality of process hardware to perform a process flow step.

20                  18.   The method of Claim 16 further including a step of communicating a recipe state, at least one unit operation state, and at least one device state to a workstation.

                  19.   The method of Claim 16 further including a step of receiving a reset command and initializing the computer system before said step of receiving said  
25   recipe.

20. The method of Claim 16 wherein said process control module communicates with a hardware control module responsible for providing an interface to a plurality of process hardware.

21. The method of Claim 16 wherein said execution loop further includes  
5 a step of correlating one of a plurality of input/output points with one of a plurality of hardware devices, thereby allowing said process control module to communicate with a hardware control module.

22. The method of Claim 16 wherein said execution loop further includes  
10 a step of correlating one of a plurality of hardware devices with one of a plurality of input/output points, thereby allowing a hardware control module to communicate with said process control module.

23. The method of Claim 16 further including a step of performing data acquisition from a plurality of selected devices of a plurality of process hardware, said step of performing data acquisition performed by a hardware control module,  
15 sending a plurality of acquired information to said process control module from a hardware control module.

24. A computer system for automating a sequence of process flow operations, said computer system comprising:

a controller having an input/output component and a processing  
20 component, said input/output component for communicating with a workstation and a plurality of process hardware, said processing component programmed to execute a process including the steps of:

receiving a recipe, said recipe including a plurality of unit operations,  
each of said plurality of unit operations describing a process flow step in  
25 terms of at least one chemical and/or physical step to be performed;

receiving a command to begin execution of said recipe,

performing an execution loop wherein said plurality of unit operations are executed, said execution loop including the steps of:

executing one of said plurality of unit operations,

determining if a next one of said plurality of unit operations is executable in parallel with said one of said plurality of unit operations and, if so, executing said next one of said plurality of unit operations and repeating said step of determining until said next one of said plurality of unit operations is determined not to be executable in parallel, and

waiting for execution of said one of said plurality of unit operations to be completed if said next one of said plurality of unit operations is determined not to be executable in parallel with said one of said plurality of unit operations.

25. The computer system of Claim 24 wherein said step of executing one of said plurality of unit operations includes a step of passing a set of data to a hardware control module from a process control module, executing a set of instructions by said hardware control module to manipulate said plurality of process hardware to perform said process flow step defined by said one of said plurality of unit operations.

26. The computer system of Claim 24 further including said workstation having a processing component, said workstation processing component programmed to execute a process including the steps of:

providing a recipe editor for creating and maintaining said recipe,

providing operations control for executing said recipe, and

displaying at least one process variable during execution of said recipe.

27. The computer system of Claim 24 further including said plurality of process hardware in communication with said input/output component of said controller and responsive to at least one control signal transmitted by said controller, said plurality of process hardware adapted to produce a  
5 radiopharmaceutical and including a reagent delivery system and a reaction vessel with an associated heating and purging system.

28. The computer system of Claim 24 wherein said workstation communicates said recipe and at least one command to a process control program being executed by said controller.

10 29. The computer system of Claim 24 wherein a process control program being executed by said controller communicates a recipe state, at least one unit operation state, and at least one device state to said workstation.

30. The computer system of Claim 24 wherein said controller processing component is programmed to execute a process further including a step of  
15 receiving a reset command and initializing said controller before said step of receiving said plurality of unit operations.

31. The computer system of Claim 24 wherein said processing component further executes a process step including correlating each of a plurality of input/output points to a corresponding one of a plurality of hardware devices  
20 whereby said process control module receives data from one of said plurality of input/output points and said process control module determines said corresponding one of said plurality of hardware devices.

32. The computer system of Claim 24 wherein said processing component further executes a process step including correlating each of a plurality of  
25 hardware devices to a corresponding one of a plurality of input/output points whereby a hardware control module determines said corresponding one of said



plurality of input/output points and said hardware control module communicates with one of said plurality of input/output points.

33. The computer system of Claim 24 wherein said processing component further executes a process step including performing data acquisition from a plurality of selected devices of said plurality of process hardware, said step of performing data acquisition performed by a hardware control module, said hardware control module sending a plurality of acquired information to said process control module.

34. A controller for automating a sequence of process flow operations, said controller comprising:

an input/output component adapted to communicate with a workstation and a plurality of process hardware; and

a processing component programmed to execute a process including the steps of:

receiving a recipe including a plurality of unit operations, each of said plurality of unit operations describing a process flow step in terms of at least one chemical and/or physical step to be performed;

receiving a command to begin execution of said recipe,

performing an execution loop wherein said plurality of unit operations are executed, said execution loop including the steps of:

executing one of said plurality of unit operations and starting a parallel group,

classifying a next one of said plurality of unit operations as one of a parallel operation and a sequential operation,

executing said parallel operation as part of said parallel group  
and repeating said step of classifying,

waiting for said parallel group to complete execution,

executing said sequential operation and starting a new parallel  
5 group, and

repeating said step of classifying.

35. The controller of Claim 34 wherein said step of executing one of said  
plurality of unit operations, said step of executing said parallel operation, and said  
step of executing said sequential operation each including a step of passing a set of  
10 data to a hardware control module from a process control module, said hardware  
control module executing a set of instructions including a step of manipulating  
said plurality of process hardware to perform said process flow step.

36. The controller of Claim 34 wherein a process control program being  
executed by said controller communicates a recipe state, at least one unit  
15 operation state, and at least one device state to a workstation.

37. The controller of Claim 34 wherein said a process further includes  
receiving a reset command and initializing said controller before said step of  
receiving said recipe.

38. The controller of Claim 34 further including the step of storing said  
20 recipe in a queue after said step of receiving said recipe.

39. The controller of Claim 34 further including a correlating one of a  
plurality of devices to one of a plurality of input/output points, whereby a set of  
data is passed between a process control program and a hardware control  
program, said process control program dealing with said plurality of devices and  
25 said hardware control program dealing with said plurality of input/output points.

40. The controller of Claim 34 wherein said processing component further includes a step for data acquisition from a plurality of selected devices of said plurality of process hardware.

41. A controller for automating a sequence of process flow operations,  
5 said controller comprising:

an input/output component adapted to communicate with a workstation and a plurality of process hardware;

a process control program for executing a recipe including a plurality of unit operations, each of said plurality of unit operations describing a process flow step  
10 in terms of at least one chemical and/or physical step to be performed, said process control program receiving said recipe through said input/output component;

a hardware control program for monitoring and controlling said plurality of process hardware through said input/output component, said process control  
15 program communicating with said hardware control program; and

a processing component programmed to execute said process control program and said hardware control program.

42. The controller of Claim 41 wherein said process control program is programmed to execute a process including the steps of:

20 receiving said plurality of unit operations, each of said plurality of unit operations describing a process flow step in terms of at least one chemical and/or physical step to be performed;

receiving a command to begin execution of said recipe,

performing an execution loop wherein said plurality of unit operations are  
25 executed, said execution loop including the steps of:

executing one of said plurality of unit operations and starting a parallel group,

classifying a next one of said plurality of unit operations as one of a parallel operation and a sequential operation,

5            executing said parallel operation as part of said parallel group and repeating said step of classifying,

             waiting for said parallel group to complete execution,

             executing said sequential operation and starting a new parallel group, and

10           repeating said step of classifying.

43.    The controller of Claim 41 wherein said hardware control program is programmed to execute a process including the steps of:

             receiving a set of values from said process control program;

             sending a set of data to a selected device of said plurality of process  
15    hardware, said set of data corresponding to said set of values.

44.    The controller of Claim 41 wherein said hardware control program is programmed to execute a process including the steps of:

             receiving a set of data from a selected device of said plurality of process hardware;

20           sending a set of values to said process control program, said set of data corresponding to said set of values.

45.    The controller of Claim 41 wherein said process control program includes a plurality of process objects representing a plurality of process elements,

each of said plurality of process objects including at least one property and at least one method for manipulating one of said plurality of process elements.

46. The controller of Claim 41 wherein said hardware control program includes a plurality of hardware objects each representing a hardware device from  
5 said plurality of process hardware, each of said plurality of hardware objects including at least one property and at least one method for directly monitoring and/or controlling said hardware device.

47. The controller of Claim 41 wherein said process control program includes a plurality of process objects representing a plurality of process elements  
10 and said hardware control program includes a plurality of hardware objects each representing a hardware device from said plurality of process hardware, each of said plurality of process objects including at least one property and at least one method for manipulating one of said plurality of process elements, each of said plurality of hardware objects including at least one property and at least one  
15 method for directly monitoring and/or controlling said hardware device, said plurality of process objects communicating with said plurality of hardware objects.

48. The controller of Claim 41 wherein said process control program and said hardware control program execute a process including a step of correlating one of a plurality of devices to one of a plurality of input/output points, whereby a  
20 set of data is passed between said process control program and said hardware control program, said process control program dealing with said plurality of devices and said hardware control program dealing with said plurality of input/output points.

49. The controller of Claim 41 wherein said process control program  
25 passes a set of data to said hardware control program, said hardware control program executing a set of instructions manipulating said plurality of process hardware to perform said process flow step defined by said one of said plurality of unit operations.

50. The controller of Claim 41 wherein said process control program executes a step of communicating a recipe state, at least one unit operation state, and at least one device state to a workstation.

51. The controller of Claim 41 wherein said hardware control program  
5 performs data acquisition from a plurality of selected devices of said plurality of process hardware.

52. A controller for automating a sequence of process flow operations, said controller comprising:

an input/output component adapted to communicate with a workstation  
10 and a plurality of process hardware; and

a process control program for executing a recipe including a plurality of unit operations, each of said plurality of unit operations describing a process flow step in terms of at least one chemical and/or physical step to be performed, said process control program receiving said recipe through said input/output  
15 component, said process control program including a plurality of process objects representing a plurality of process elements, each of said plurality of objects including at least one property and at least one method for manipulating one of said plurality of process elements;

a hardware control program for monitoring and controlling said plurality of  
20 process hardware through said input/output component, said hardware control program including a plurality of hardware objects each representing a hardware device from said plurality of process hardware, each of said plurality of objects including at least one property and at least one method for directly monitoring and/or controlling said hardware device, said plurality of process objects  
25 communicating with said plurality of hardware objects; and

a processing component programmed to execute said process control program and said hardware control program.

53. A computer system for automating a sequence of process flow operations, said computer system comprising:

a means for receiving a recipe;

a means for initiating execution of said recipe; and

5 a means for executing a plurality of unit operations making up said recipe.

54. The computer system of Claim 53 further including a means for data acquisition from a plurality of selected devices of a plurality of process hardware.

55. A computer system for automating a sequence of process flow operations, said computer system comprising:

10 a means for editing a recipe;

a means for sending said recipe to a controller;

a means for sending an execution command to a controller; and

a means for monitoring a process flow defined by said recipe.

56. At least one computer programmed to execute a process for  
15 automating a sequence of process flow operations, said process comprising:

receiving a recipe including a plurality of unit operations, each of said plurality of unit operations describing a process flow step in terms of at least one chemical and/or physical step to be performed;

receiving a command to begin execution of said recipe; and

20 performing an execution loop wherein said plurality of unit operations are executed, said execution loop including the steps of:

executing one of said plurality of unit operations and starting a parallel group,

classifying a next one of said plurality of unit operations as one of a parallel operation and a sequential operation,

5            executing said parallel operation as part of said parallel group and repeating said step of classifying,

continuing execution of said parallel group until each of said plurality of unit operations in said parallel group is complete,

10            executing said sequential operation and starting a new parallel group, and

repeating said step of classifying.

57.    The process of Claim 56 further including a step of receiving a reset command and initializing the computer system before said step of receiving said recipe.

15            58.    The process of Claim 56 further including a step of communicating a recipe state, at least one unit operation state, and at least one device state to a workstation.

20            59.    The process of Claim 56 wherein said step of executing one of said plurality of unit operations, said step of executing said parallel operation, and said step of executing said sequential operation each includes a step of passing a set of data to a hardware control module from a process control module, said hardware control module performing a set of instructions manipulating said plurality of process hardware to perform said process flow step.



60. The process of Claim 56 further including a step of performing data acquisition from a plurality of selected devices of a plurality of process hardware, said step of performing data acquisition performed by a hardware control module, said hardware control module sending a plurality of acquired information to a process control module.

61. The process of Claim 56 further including a step of correlating one of a plurality of devices to one of a plurality of input/output points, whereby a set of data is passed between a process control program and a hardware control program, said process control program dealing with said plurality of devices and said hardware control program dealing with said plurality of input/output points.

62. A program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine to perform method steps for automating a sequence of process flow operations, said method comprising:

receiving a recipe including a plurality of unit operations, each of said plurality of unit operations describing a process flow step in terms of at least one chemical and/or physical step to be performed;

receiving a command to begin execution of said recipe,

performing an execution loop wherein said plurality of unit operations are executed, said execution loop including the steps of:

executing one of said plurality of unit operations and starting a parallel group,

classifying a next one of said plurality of unit operations as one of a parallel operation and a sequential operation,

executing said parallel operation as part of said parallel group and repeating said step of classifying,

waiting for said parallel group to complete execution,

executing said sequential operation and starting a new parallel group,  
and

repeating said step of classifying.

63. The method of Claim 62 further including a step of receiving a reset  
5 command and initializing a controller before said step of receiving said recipe.

64. The method of Claim 62 further including a step of communicating a  
recipe state, at least one unit operation state, and at least one device state to a  
workstation.

65. The method of Claim 62 wherein said step of executing one of said  
10 plurality of unit operations, said step of executing said parallel operation, and said  
step of executing said sequential operation each include a step of passing a set of  
data to a hardware control module from a process control module, said hardware  
control module executing a set of instructions manipulating said plurality of  
process hardware to perform said process flow step.

15 66. The method of Claim 62 further including a step of using a lookup  
table correlating one of a plurality of devices to one of a plurality of input/output  
points, whereby a set of data is passed between a process control program and a  
hardware control program, said process control program dealing with said plurality  
of devices and said hardware control program dealing with said plurality of  
20 input/output points.

67. The method of Claim 62 further including a step of performing data  
acquisition from a plurality of selected devices of a plurality of process hardware.

68. Computer readable media tangibly embodying a program of  
instructions executable by a computer to perform a method of automating a  
25 sequence of process flow operations, said method comprising:

receiving a recipe including a plurality of unit operations, each of said plurality of unit operations describing a process flow step in terms of at least one chemical and/or physical step to be performed;

receiving a command to begin execution of said recipe; and

5 performing an execution loop wherein said plurality of unit operations are executed, said execution loop including the steps of:

executing one of said plurality of unit operations,

determining if a next one of said plurality of unit operations is  
executable in parallel with said one of said plurality of unit operations and,  
10 if so, executing said next one of said plurality of unit operations and  
repeating said step of determining until said next one of said plurality of  
unit operations is determined not to be executable in parallel, and

waiting for execution of said one of said plurality of unit operations to  
be completed if said next one of said plurality of unit operations is  
15 determined not to be executable in parallel with said one of said plurality of  
unit operations.

69. Media as in Claim 68 wherein said method further includes a step of receiving a reset command and initializing a controller before said step of receiving said recipe.

20 70. Media as in Claim 68 wherein said method further includes a step of communicating a recipe state, at least one unit operation state, and at least one device state to a workstation.

71. Media as in Claim 68 wherein said method further includes a step of  
using a lookup table to correlate one of a plurality of input/output points to one of  
25 a plurality of hardware devices.

72. Media as in Claim 68 wherein said method further includes a step of performing data acquisition from a plurality of selected devices of a plurality of process hardware.

73. Computer readable media tangibly embodying a program of  
5 instructions executable by a computer to perform a method of automating a sequence of process flow operations, said method comprising:

providing a recipe editor for creating and maintaining a recipe;

providing an operations control for executing said recipe; and

displaying at least one process variable during execution of said recipe.

10 74. Media as in Claim 73 wherein said method step of providing said operations control includes the steps of:

selecting from a library said recipe for execution,

sending said recipe to said controller, and

sending an execute command to said controller.

15 75. Media as in Claim 73 wherein said method step of providing said recipe editor includes the steps of:

presenting a first list to the user, said first list including a plurality of available unit operations;

presenting a recipe list to the user, said recipe list including a plurality of  
20 selected unit operations defining said recipe;

presenting a resource list to the user, said resource list including a plurality of resources based on said plurality of selected unit operations;

allowing the user to add at least one of said plurality of available unit operations to said recipe list;

allowing the user to delete at least one of said plurality of selected unit operations from said recipe list; and

5 allowing the user to edit at least one of said plurality of resources for one of said plurality of selected unit operations.

76. A computer readable medium containing a data structure for automating a sequence of process flow operations, said data structure comprising:

10 a list table containing a set of recipe data including a list of at least one recipe;

a recipe table containing a set of unit operation data including a list of a plurality of unit operations, said recipe table containing a set of recipe live data, said recipe live data including a recipe status, a recipe start time and date, and a recipe finish time and date; and

15 a unit operation table containing a set of parameters relating to each of said plurality of unit operations, said unit operation table containing a set of unit operation live data, said unit operation live data including a unit operation status, a unit operation start time and date, and a unit operation finish time and date.

20 77. An interface for processing an automated sequence of process flow operations, the interface comprising computer readable program code devices for:

accepting a plurality of unit operations forming a recipe;

accepting an execute command to initiate execution of a loop wherein said plurality of unit operations are executed, said loop including the steps of:

25 executing one of said plurality of unit operations and starting a parallel group,

classifying a next one of said plurality of unit operations as one of a parallel operation and a sequential operation,

executing said parallel operation as part of said parallel group and repeating said step of classifying,

5                   waiting for said parallel group to complete execution,

executing said sequential operation and starting a new parallel group,  
and

repeating said step of classifying; and

10                   sending a data stream including a recipe state, a unit operation state, and at least one device state.

78.     A method in a computer system for editing a recipe by a user, comprising:

presenting to the user a first list of a plurality of available unit operations;

15                   presenting to the user a recipe list of a plurality of selected unit operations  
defining said recipe;

presenting to the user a resource list including a plurality of resources based on said plurality of selected unit operations;

allowing the user to add at least one of said plurality of available unit operations to said recipe list;

20                   allowing the user to delete at least one of said plurality of available unit operations from said recipe list; and

allowing the user to edit the resources for one of said plurality of selected unit operations.